The Development of Registries for Surveillance of Adult Lead Exposure, 1981 to 1992

ABSTRACT

Objectives. Since 1981, 15 states have established registries for surveillance of adult lead absorption, primarily based on reports of elevated blood lead levels from clinical laboratories. I review the status of the registries and recommend steps for further development.

Methods. Companies reported to the New York registry are compared with those cited by the Occupational Safety and Health Administration (OSHA). I present data on US workers and plants with potential lead exposures and blood tests, as well as review registries' reporting requirements.

Results. Registries identify many companies not cited by the Occupational Safety and Health Administration, but underreporting occurs because (1) reporting is usually not required from laboratories outside the state, (2) most registries use a blood lead reporting level of 1.21 μmol/L, which excludes many exposed workers, and (3) many companies with potential exposures do not have routine monitoring programs.

Conclusions. Registries' reporting requirements and procedures should be standardized, including a blood lead reporting level of 0.72 μmol/L. Elevated blood lead levels should be a reportable condition nationwide, and a comprehensive national surveillance system should be established: clinical laboratories should be required to report cases to those states with lead registries or directly to the national adult lead registry. (*Am J Public Health.* 1992;82:1113–1118)

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Introduction

Lead adversely affects the hematologic, central and peripheral nervous, cardiovascular, renal, and reproductive systems.[1] A variety of surveillance methods have been proposed to identify, first, morbidity and mortality potentially associated with lead exposures and, second, companies or workers with lead exposures.[2–7] The National Occupational Exposure Survey (NOES),[8] conducted from 1981 to 1983, estimated that almost 1.4 million workers were exposed to inorganic lead or lead compounds (Table 1). Many industries have airborne lead concentrations greater than the permissible exposure limit (PEL) set by the Occupational Safety and Health Administration (OSHA), which is 50 $\mu g/m^3$ averaged over an 8-hour work shift.[9,10] Furthermore, the prevalence and severity of exposures in a number of industries with high lead exposures have not declined in recent years.[10]

The OSHA lead standard requires that companies provide industrial hygiene and medical surveillance programs (including measurement of blood lead levels) when airborne lead concentrations exceed 30 $\mu g/m^3$ averaged over an 8-hour work shift.[9] A worker must be removed from exposure if (1) the mean blood lead level of the worker's last three tests, or the mean of all of the worker's tests over the previous 6 months, is greater than or equal to 2.42 μmol/L (1 μmol/L = 20.72 μg/dL); or (2) any test is greater than or equal to 2.90 μmol/L; or (3) the worker's medical condition contraindicates continued lead exposure.

Methods and Results

In 1981, the New York State Health Department began population surveillance of adult lead exposure, using blood lead results from industrial medical surveillance programs and other sources.[7] State statutes require clinical laboratories, employers, and health facilities to report individuals with elevated levels of heavy metals in blood and urine samples. State agencies provide follow-up, which includes education for employers, workers, and clinicians, industrial hygiene evaluations, and medical consultation.

Adult lead registries have been established in 15 states, primarily based on reporting from clinical laboratories (Table 2). Through 1990, the New York registry had received reports on 4735 workers from 695 companies or work sites; the New Jersey registry, 2851 workers from 271 companies; the California registry, 2779 workers from 250 companies;[11] and the Texas registry, 1116 workers from 101 companies. Many of these companies had employees with markedly elevated blood lead levels. Of the 695 work sites reported to the New York registry, 197 (28.3%) had at least one employee with blood lead levels exceeding the OSHA medical removal protection levels. These included 15 of 34 heavy construction companies (44.1%; Standard Industrial Classification[12] [SIC] 16), 27 of 61 special trade contractors (44.3%; SIC 17), 22 of 43 primary metal industries (51.2%; SIC 33), 17 of 32 fabricated metal product companies (53.1%; SIC 34), 13 of 25 scrap

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TABLE 1—Workers and Plants with Potential Inorganic Lead Exposures,[a] by Major Industrial Group, from the National Occupational Exposure Survey (NOES), 1981 to 1983

NOES Major Industrial Group (Standard Industrial Classification)	Workers: Total No. (SE)	Workers: With Potential Lead Exposure[b] No. (SE)[d]	Workers: With Potential Lead Exposure[b] % of Total Workers	Workers: With Blood Tests[c] No. (SE)[d]	Workers: With Blood Tests[c] % of Workers with Lead Exposure	Plants: Total No. (SE)[d]	Plants: With Potential Lead Exposure[b] No. (SE)[d]	Plants: With Potential Lead Exposure[b] % of Total Plants	Plants: With Blood Tests[c] No. (SE)[d]	Plants: With Blood Tests[c] % of Plants with Lead Exposure
Agricultural services (7)	110 692 (29 333)	0 ...	0.0	0 ...	...	5633 (1557)	0 ...	0.0	0 ...	...
Oil and gas extraction (13)	414 284 (101 840)	45 600 (6840)	11.0	0 ...	0.0	9662 (2132)	2064 (722)	21.4	0 ...	0.0
Construction (15–17)	3 072 049 (132 323)	198 790 (19 879)	6.5	1812 (652)	0.9	98 791 (2409)	12 079 (2657)	12.2	183 (121)	1.5
Manufacturing (20–39)	19 261 829 (551 881)	900 643 (63 045)	4.7	318 147 (28 633)	35.3	191 266 (3668)	39 716 (6355)	20.8	5953 (1548)	15.0
Transportation (40–49)	3 160 926 (293 218)	113 464 (13 616)	3.6	32 085 (5454)	28.3	59 465 (3540)	10 935 (2406)	18.4	873 (384)	8.0
Wholesale/retail trade (50–59)	1 533 201 (142 606)	15 103 (3021)	1.0	3245 (1006)	21.5	61 051 (3970)	3643 (1093)	6.0	537 (268)	14.7
Services (70–79)	2 197 247 (133 603)	79 573 (10 344)	3.6	13 556 (2847)	17.0	75 835 (3590)	8130 (1951)	10.7	319 (185)	3.9
Health services (80)	3 658 805 (351 918)	24 612 (4430)	0.7	21 994 (3959)	89.4	7067 (851)	1514 (575)	21.4	1347 (525)	89.0
Total	33 409 033 (762 445)	1 377 785 (96 445)	4.1	390 839 (31 267)	28.4	508 770 (8254)	78 081 (10 150)	15.3	9212 (2119)	11.8

Sources. Data from NOES[8] and Standard Industrial Classification Manual.[12]

[a]Inorganic lead in lead ore, lead compounds/complexes, lead alloys, and lead in welding, brazing, and soldering. An estimated 222 207 ± 22 221 workers were exposed to organolead compounds.

[b]Potential or inferred exposure is annual average exposure ≥ 30 minutes/week, or usage ≥ once/week for 90% of weeks/year.

[c]"Blood tests" is an affirmative answer to the question of blood tests provided to selected or all employees, with the exception of tests provided only to executive or management employees. The question does not specifically refer to lead.

[d] ... = not available. SEs were estimated using coefficients based on a nonlinear regression of 792 SEs for different-sized estimates from 44 SIC groups; at present, SEs cannot be estimated for zero values or for percentages.

and waste material companies (52.0%; SIC 5093), and 20 of 84 automotive repair shops (23.8%; SIC 7539).

Although many workers and companies are reported to registries, registries underestimate the prevalence of occupational lead exposure because only a small fraction of companies with potential lead exposures perform routine biological monitoring. A survey of California lead-using companies estimated that only 2.6% ever performed environmental monitoring and only 1.4% had routine biological monitoring.[13] Using different methods in a national sample,[8] the NOES estimated that 11.8% of companies with potential inorganic lead exposures had blood tests performed on employees (Table 1). The prevalence of routine biological monitoring is especially low in small companies and the construction industry,[8,13,14] which has a permissible exposure limit of 200 μg/m^3 and no OSHA requirements for routine air or blood sampling.[15] The NOES estimated that only 0.1% of 198 790 lead-exposed construction workers received blood tests and that there were no blood tests for exposed workers in oil and gas extraction (SIC 13), auto repair, services, and garages (SIC 75), and miscellaneous repair services (SIC 76).

Lead registries complement OSHA inspections in two ways. First, registries detect many companies not cited by OSHA,[7,16] whose inspection program focuses on larger manufacturing companies with well-recognized lead hazards. Through 1990, only 76 of the 695 work sites (10.9%) reported to the New York registry were also cited by OSHA. These included 62 of 187 manufacturing companies (33.2%) but only 14 of 508 nonmanufacturing companies (2.8%) ($P < .001$, chi-square test). Second, registry data and OSHA inspection results can be used to target interventions because companies detected by both methods have particularly high exposures.[12] Through 1990, 580 New York companies were cited by OSHA for violations of the federal lead standard. Of 76 cited companies that were also reported to the New York registry, 49 (64.5%) were cited for airborne lead concentrations above the permissible exposure limit, compared with 70 of 504 companies (13.9%) cited by OSHA but not reported to the registry ($P < .001$, chi-square test).

Recommendations for Registry Development

The reporting requirements and procedures vary among states (Table 2) and should be standardized to ensure wider and more uniform reporting and a common basis for interventions and data comparisons.

1. *Blood lead reporting level.* A level of 0.72 μmol/L or lower should be adopted, as four states have done. The probability of detecting excessive expo-

TABLE 2—Reporting Requirements for Adult Lead Registries, 1992

State (Start Date)	Contact Person, Address, and Telephone Number	Blood Lead Reporting Level (μmol/L)	Other Heavy Metals	Required to Report to Registry, Days	Age at Which Person Is Defined as an Adult, y	Reporting Also Required from Individual Clinicians and Health Facilities?
Alabama (11/90)	Charles Woernle, MD, MPH State Epidemiologist Department of Public Health 434 Monroe Street Montgomery, AL 36130 (205) 242-5131	0.72	None	7	18	Yes
California (1/87)	Ana Maria Osorio, MD, MPH Occupational Health Program California Department of Health Services 2151 Berkeley Way, Room 504 Berkeley, CA 94704 (510) 540-2115	1.21	None	3	16	No
Colorado (10/88)	Jane McCammon Epidemiology Division Colorado Department of Health 4210 E 11th Avenue Denver, CO 80220 (303) 331-8330	1.21	Mercury Arsenic Cadmium	30	18	No
Connecticut (1/91)[a]	Narda Tolentino, MPH Environmental Epidemiology and Occupational Health Connecticut Department of Health Services 150 Washington Street Hartford, CT 06106 (203) 566-8167	1.21	None	Not stated	16	Yes
Illinois (4/90)	Melinda Lehnherr Occupational Disease Registry Division of Epidemiologic Studies Illinois Department of Public Health 605 W Jefferson Springfield, IL 62761 (217) 785-1873	1.21	None	7	16	No
Iowa[b] (10/90)	Russell Currier, DVM, MPH Environmental Epidemiology Section Iowa Department of Public Health Lucas State Office Building Des Moines, IA 50319 (515) 281-5643	All levels reportable	Mercury Arsenic Cadmium	Not stated	15	Yes
Maryland (2/88)	Ellen Coe, RN, MPH Health Registries Division Maryland Department of the Environment 2500 Broening Highway Baltimore, MD 21224 (410) 631-3851	1.21	Mercury Arsenic Cadmium	5	18	No
Massachusetts (4/91)	Richard Rabin Division of Occupational Hygiene Massachusetts Department of Labor and Industries 1001 Watertown Street West Newton, MA 02165 (617) 969-7177	0.72	None	7	15	No
Michigan (3/92)	Flint Watt, MBA, CIH Division of Occupational Health Michigan Department of Public Health 3423 N Logan Boulevard Lansing, MI 48909 (517) 335-8250	1.93	None	3	16	No

(Continued on next page)

TABLE 2—(Continued)

State (Start Date)	Contact Person, Address, and Telephone Number	Blood Lead Reporting Level (μmol/L)	Other Heavy Metals	Required to Report to Registry, Days	Age at Which Person Is Defined as an Adult, y	Reporting also Required from Individual Clinicians and Health Facilities?
New Jersey (10/85)	Barbara Gerwel, MD Occupational Disease Prevention Program New Jersey Department of Health C N 360, John Fitch Plaza Trenton, NJ 08625 (609) 984-1863	1.21	Mercury Arsenic Cadmium	Immediately	16	Yes
New York (9/81)	Robert Stone, PhD Division of Occupational Health New York State Department of Health 2 University Place, Room 155 Albany, NY 12203-3313 (518) 458-6228	1.21[d]	Mercury Arsenic Cadmium	10	18	Yes
Oregon (9/90)	Jane Gordon, PhD Deputy State Epidemiologist Oregon Health Division 800 NE Oregon Street, #21 Portland, OR 97232 (503) 731-4025	1.21	None	7	18	No
Texas (10/85)	Teresa Willis Texas Department of Health 1100 West 49th Street Austin, TX 78756 (512) 458-7268	1.93	None	Not stated	15	Yes
Utah[b] (1/90)	Denise Beaudoin, MD, MSPH Bureau of Epidemiology Utah Department of Health P.O. Box 16660 Salt Lake City, UT 84116-0660 (801) 538-6191	0.72[e]	None	60	18	Yes
Wisconsin (12/87)	Larry Hanrahan, MS Bureau of Epidemiology Wisconsin Department of Health and Social Services One W Wilson Street, Box 309 Madison, WI 53701 (608) 267-7173	1.21	None	2	16	Yes
CDC-NIOSH (1/87; data from existing registries)	Paul J. Seligman, MD, MPH Surveillance Branch National Institute for Occupational Safety and Health 4676 Columbia Parkway, R-21 Cincinnati, OH 45226 (513) 841-4353	...	None	...	...	...

Sources. State registries and the Centers for Disease Control's National Institute for Occupational Safety and Health (CDC–NIOSH) registry.
[a]Pilot data collected from the state public health laboratory, 1989–1990.
[b]Occupational follow-up planned or under consideration.
[c]Lowered from 1.21 μmol/L, 4/92.
[d]Lowered from 1.93 μmol/L, 10/86 (1 μmol/L = 20.72 μg/dL).
[e]Lowered from 1.45 μmol/L, 12/91.

sures is related to the frequency of exposure measurement.[17] Because many companies with lead exposures do not have biological monitoring programs, a relatively low blood lead level that is incidentally reported to a registry can be indicative of higher exposures.

Most states currently have a blood lead reporting level of 1.21 μmol/L, and the number of reported cases will increase if the reporting level is set at 0.72 μmol/L. For example, 49% of the workers reported to the Alabama registry in 1991 had initial blood lead levels from 0.72 to 1.20 μmol/L. Additional personnel should be provided to ensure adequate follow-up.

2. *Other information on lead exposures.* To augment reporting based on blood lead levels, registries should reference information on lead-using companies, OSHA inspection results, and workers' compensation claims.[7,13,16,18] Some registries estimate the prevalence of elevated lead absorption by determining the

number of potentially exposed workers, using a questionnaire; the California questionnaire is a good model. The Iowa registry requires the reporting of the results of all blood tests. Work histories should be elicited from workers aged 15 and older, in order to include those who leave school before age 18 and students with summer or part-time jobs.

3. *Other heavy metals.* Increased absorption of mercury, arsenic, and cadmium should be reported. Through 1990, the New York registry received reports on 1505 mercury cases from 70 companies (including many workers from a chlor-alkali plant), 151 arsenic cases from 22 companies, and 63 cadmium cases from 18 companies.

4. *Response time.* To expedite follow-up in the most serious cases, blood lead levels above 2.42 μmol/L (the OSHA biological limit value) should be reported within 24 hours. Through 1990, only 24.7% of New York tests above 2.42 μmol/L were reported within 10 days and 63.7% within 30 days; only 19.1% of all tests were reported within 10 days, the statutory requirement. In 1987, only 9% of California tests were reported within 3 days.[19]

5. *Reporting sources.* Clinicians are required by many states to report lead or heavy metals poisoning[20] and should also report directly to registries. In practice, employers, health facilities, and clinicians send samples to laboratories, which then send the results to registries. In New York, through 1990 93.4% of workers and 95.9% of companies have been reported by laboratories, alone or jointly with other sources. Laboratories should be audited to ensure that all cases have been reported, as the New York registry has done.

6. *Location of reporting sources.* Reporting should be sought from out-of-state laboratories because clinical laboratories do not have strictly local clients. Of the 15 state registries, only New York requires reporting from all laboratories that analyze blood from state residents. Thirty-three of the 72 laboratories reporting to the New York registry are located outside the state; through 1990, 80.5% of workers and 77.0% of companies have been reported from these laboratories. An estimated 47% of blood lead samples from biological monitoring programs in California are analyzed by laboratories outside the state.[13]

Several methods can be used to broaden reporting from clinical laboratories. All states should designate elevated blood lead levels as a reportable condition and, as in New York, should use or create licensing authority to require reporting from both in-state and out-of-state laboratories. Alternatively, federal legislation could be enacted for these purposes. Blood lead levels from residents of states without registries should be reported directly to the national adult lead registry, which could then share the data with state health and labor departments. The national registry, at the Centers for Disease Control's National Institute for Occupational Safety and Health (CDC-NIOSH), uses data from existing registries (Table 2).

7. *Identification of laboratories.* Commercial, public health, and university hospital laboratories that analyze lead in childhood and adult blood samples can be identified in several ways. Some laboratories participate in proficiency testing programs operated by the College of American Pathologists (about 300 laboratories), the CDC (about 200 laboratories), and the state health departments of New York and Pennsylvania (about 70 laboratories each). About 250 of these laboratories ask the OSHA Salt Lake Technical Center to determine whether their performance meets OSHA requirements for biological monitoring.

The principal laboratories that test for lead and other toxins in biological samples can also be identified from a national survey by the Health Care Financing Administration. The survey is being conducted to support the Clinical Laboratory Improvement Amendments (CLIA) of 1988, which require certification for laboratories that test human materials for diagnosis or treatment.[21] It is expected that 200 000 to 250 000 facilities will be identified from the 640 000 potential facilities to which questionnaires have been sent. The questionnaire includes the number, type, and methodology of laboratory procedures and the qualifications of the supervisors and technicians. The CLIA also require certification for noncommercial laboratories (e.g., those operated within manufacturing industries), but these laboratories are not included in the survey.

Conclusion

New methods and additional resources are needed to achieve the national health objective of eliminating occupational lead exposures resulting in blood lead levels above 1.21 μmol/L.[1,22] Adult lead registries complement other forms of surveillance in identifying companies with excessive lead exposures. Reporting requirements and procedures should be standardized. Elevated blood lead levels should be a reportable condition nationwide, and a comprehensive national surveillance system should be established: clinical laboratories, regardless of location, should report cases to states with adult lead registries or, with those cases from states without registries, directly to the CDC-NIOSH registry. □

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References

1. Landrigan PJ, Silbergeld EK, Froines JR, Pfeffer RM. Lead in the modern workplace. *Am J Public Health.* 1990;80:907–908 (erratum 1991;81:162).
2. Rutstein DD, Mullan RJ, Frazier TM, Halperin WE, Melius JM, Sestito JP. Sentinel health events (occupational): a basis for physician recognition and public health surveillance. *Am J Public Health.* 1983;73:1054–1062.
3. Froines JR, Dellenbaugh CA, Wegman DH. Occupational health surveillance: a means to identify work-related risks. *Am J Public Health.* 1986;76:1089–1096.
4. Seligman PJ, Halperin WE, Mullan RJ, Frazier TM. Occupational lead poisoning in Ohio: surveillance using workers' compensation data. *Am J Public Health.* 1986;76:1299–1302.
5. Baker EL. Sentinel Event Notification System for Occupational Risks (SENSOR): the concept. *Am J Public Health.* 1989;79(suppl):18–20.
6. Froines J, Wegman D, Eisen E. Hazard surveillance in occupational disease. *Am J Public Health.* 1989;79(suppl):26–31.
7. Baser ME, Marion D. A statewide case registry for surveillance of occupational heavy metals absorption. *Am J Public Health.* 1990;80:162–164.
8. National Institute for Occupational Safety and Health. *National Occupational Exposure Survey.* Vols. 1–3. Washington, DC: US Dept of Health and Human Services; 1988, 1990. US Dept of Health and Human Services publications NIOSH 88–106, NIOSH 89–102, NIOSH 89–103.
9. Occupational Safety and Health Standards. Subpart Z: Toxic and hazardous substances—lead. Washington, DC: Office of the Federal Register, National Archives and Records Administration; 1985. 29 CFR § 1910.1025.
10. Froines JR, Baron S, Wegman D, O'Rourke S. Characterization of the airborne concentrations of lead in U.S. industry. *Am J Ind Med.* 1990;18:1–17.
11. Maizlish NA, Rudolph LA, Royce S, et al. *Elevated Blood Lead in California Adults, 1987–1990.* Berkeley, Calif: California Department of Health Services; 1991. Publication CDHS (COHP) SR90-001.

12. Office of Management and Budget. *Standard Industrial Classification Manual.* Washington, DC: US Government Printing Office; 1987.
13. Rudolph L, Sharp DS, Samuels S, Perkins C, Rosenberg J. Environmental and biological monitoring for lead exposure in California workplaces. *Am J Public Health.* 1990;80:921–925.
14. Goldman RH, Baker EL, Hannen M, Kamerow DB. Lead poisoning in automobile radiator mechanics. *N Engl J Med.* 1987; 317:214–218.
15. Safety and Health Regulations for Construction. Subpart J: Welding and cutting—welding, cutting, and heating in way of preservative coatings. Washington, DC: Office of the Federal Register, National Archives and Records Administration; 1988. 29 CFR § 1926.354.
16. Seligman PJ, Halperin WE. Targeting of workplace inspections for lead. *Am J Ind Med.* 1991;20:381–390.
17. Rappaport S. The rules of the game: an analysis of OSHA's enforcement strategy. *Am J Ind Med.* 1984;6:291–303.
18. Baker EL, Melius JM, Millar JD. Surveillance of occupational illness and injury in the United States: current perspectives and future directions. *J Public Health Policy.* 1988;9:198–221.
19. Maizlish N, Rudolph L, Sutton P, Jones JR, Kizer KW. Elevated blood lead in California adults, 1987: results of a statewide surveillance program based on laboratory reports. *Am J Public Health.* 1990;80:931–934.
20. Freund E, Seligman PJ, Chorba TL, Safford SK, Drachman JG, Hull HF. Mandatory reporting of occupational diseases by clinicians. *JAMA.* 1989;262:3041–3044.
21. Clinical Laboratory Improvement Amendments of 1988: Final rule (with comment). Washington, DC: Office of the Federal Register, National Archives and Records Administration; 1992. 42 CFR § 405 and others.
22. US Public Health Service. *Healthy people 2000: National Health Promotion and Disease Prevention Objectives.* Full report, with commentary. Washington, DC: US Dept of Health and Human Services; 1991. Publication PHS 91–50212.

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The Injury Control and Emergency Health Services Section will again sponsor a "late-breaker" session during the APHA 1992 annual meeting in Washington, DC. The session will be held on Tuesday, November 10, and will feature work completed within the last few months (after the deadline for consideration in the regular symposia of the APHA annual meeting).

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